

Terms-of-Trade Shocks and Optimal Investment

Another Look at the Laursen-Metzler Effect

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Macroeconomics and Growth Division
February 1995

WPS 1424

1424

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Summary findings

Conventional analyses of the effect of terms-of-trade shocks provide a misleading view of their impact on investment and the current account, says Servén, because capital goods imports are excluded from the analytical framework. He argues that such an exclusion is both arbitrary and unrealistic.

Servén reexamines the consequences of permanent and transitory changes in the terms of trade in a rational-expectations model of a small open economy with intertemporally optimizing agents, and with trade in both consumption and capital goods.

In this framework, the response to a permanent terms of trade improvement is unambiguous: The long-run capital stock, and thus investment, must rise, and the current account must deteriorate — exactly the opposite of the Laursen-Metzler effect.

A transitory improvement in the terms of trade raises saving but has an uncertain effect on investment. So, the impact on the current account is generally ambiguous and is shown to depend on three factors: the import contents of consumption and investment, the duration of the windfall, and the degree of intertemporal substitutability in both consumption *and* investment.

This paper — a product of the Macroeconomics and Growth Division, Policy Research Department — is part of a larger effort in the department to understand the macroeconomic impact of policy shifts and external shocks. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Emily Khine, room N11-061, extension 37471 (29 pages). February 1995.

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Terms-of-Trade Shocks and Optimal Investment: Another Look at the Laursen-Metzler Effect

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Conventional analyses of the effect of terms-of-trade shocks provide a misleading view of their impact on investment and the current account due to the exclusion of capital goods imports from the analytical framework -- a feature that is both arbitrary and unrealistic. This paper reexamines the consequences of permanent and transitory changes in the terms of trade in a rational-expectations model of a small open economy with intertemporally optimizing agents, and with trade in both consumption and capital goods. In the paper's framework, the response to a permanent terms of trade improvement is unambiguous: the long-run capital stock, and thus investment, must rise, and the current account must deteriorate -- exactly the opposite of the Laursen-Metzler effect. In turn, a transitory improvement in the terms of trade raises saving but has an uncertain effect on investment. Thus, the impact on the current account is generally ambiguous, and is shown to depend critically on three factors: the import contents of consumption and investment, the duration of the windfall, and the degree of intertemporal substitutability in both consumption and investment.

JEL Classification Codes: F41, E22, F32.

* I thank Peter Montiel for detailed comments, and Lawrence Bouton for efficient research assistance.

1. Introduction

Capital goods represent the leading import item for many countries. In 1990, they accounted for nearly 30 percent of total imports (and close to 33 percent of non-fuel imports) in OECD countries, and more than 33 percent in developing countries (over 37 percent of their non-fuel imports)¹. These facts indicate that investment typically has a high import content (certainly higher than consumption), particularly in less-developed economies. As a result, import prices should be expected to exert a major influence on the cost of capital and thereby on investment decisions.

However, this point has received very limited attention in open-economy macroeconomic analysis, largely due to the fact that conventional models often rule out investment imports altogether. One important area where this omission may be particularly misleading concerns the current account impact of terms of trade shocks, an issue that over the last decade has attracted renewed attention.

The analytical debate on terms-of-trade shocks has evolved around the notion, first proposed by Laursen and Metzler (1950) and Harberger (1950), that a terms-of-trade loss causes a current account deterioration, through its adverse impact on real income and thereby on saving. Since the early 1980s, this proposition has been re-examined in the context of macroeconomic models embodying spending decisions explicitly derived from intertemporal optimization. For the most part, the new literature has focused on the response of saving to changes in the terms of trade. Along these lines, Sachs (1981), Obstfeld (1982, 1983), Svensson and Razin (1983) and Svensson (1984) explored the impact of terms-of-trade shocks on the intertemporal consumption decisions of forward-looking agents in a variety of frameworks. A key result emerging from this work was the crucial distinction between permanent and transitory, anticipated and unanticipated terms-of-trade shocks, whose respective effects on saving generally differ.

More recently, the analytical perspective has been broadened by a number of papers considering

¹ These figures are derived from the UNCTAD database; imports of capital goods exclude passenger cars and other consumer durables. I am grateful to Lant Pritchett for kindly providing this data.

the current account impact of terms of trade changes in models incorporating also investment decisions likewise derived from intertemporal optimization. In this vein, Matsuyama (1988) introduces a q-based investment rule in an overlapping generations model with a Heckscher-Ohlin production structure; his analysis emphasizes the role of factor intensities in the current account response to changes in the terms of trade. Sen and Turnovsky (1989) develop an infinite-horizon model likewise incorporating capital accumulation subject to installation costs; their framework underscores the labor-leisure decision as the central mechanism of adjustment to terms-of-trade shocks. Murphy (1992) introduces a similar specification of investment in a two-sector framework with traded and nontraded goods to explore the contribution of real exchange rate adjustment to shaping the current account response to terms-of-trade disturbances. Van Wincoop (1993) investigates the consequences of a resource boom in an three-sector economy including a construction industry producing nontraded capital.

In spite of the wide variety of analytical frameworks employed by this literature, one feature common to virtually all of them is the assumption (implicit or explicit) that investment has zero import content.² This precludes any direct impact of changes in the terms of trade on the real cost of capital goods, and therefore tends to downplay the role of investment in the current account response. Yet the empirical evidence summarized above shows that such an assumption is completely unwarranted.

This paper re-examines the effects of terms-of-trade shocks in a simple model that allows for imports of both consumption and capital goods, and with saving and investment plans determined optimally. The analysis focuses on the impact of unanticipated permanent and transitory disturbances.

The results show that allowing for capital goods imports has major consequences for the validity of the Laursen-Metzler effect. A permanent terms-of-trade windfall raises investment and must cause a

² For example, Murphy (1992), Sen and Turnovsky (1989), van Wincoop (1993) and also Cha (1993), all assume that capital goods are produced only domestically. In an earlier contribution, Bruno (1982) explores the consequences of a resource boom in a two-sector economy employing traded capital goods, but under the simplifying assumption that the booming sector uses no capital. See Brock and Turnovsky (1993) for a recent overview of alternative specifications of the investment process in two-sector models.

current account deficit -- contrary to the traditional wisdom. By contrast, a temporary windfall has an ambiguous impact on the current account, except in the extreme -- albeit popular in the literature -- case of zero import content of investment, in which the current account turns initially into surplus, along Laursen-Metzler lines. In the general case, however, the current account outcome depends on the import contents, and the degree of intertemporal substitutability, of both consumption and investment.

The paper is organized as follows. Section 2 lays out the analytical model, and Section 3 describes its equilibrium dynamics. The effects of permanent and transitory terms-of-trade disturbances are explored in Section 4. Finally, Section 5 concludes.

2. A stylized model of a small open economy

To highlight the role of investment decisions for the dynamics of the current account, the analytical framework will be kept as simple as possible³. We consider an economy completely specialized in the production of a good that can be used for domestic consumption and investment, or exported. The domestic good is an imperfect substitute for an importable good which is also available for consumption and investment. Production of the domestic good makes use of capital and labor according to a constant-returns technology. The economy faces given world interest rates and goods prices. We let π denote the terms of trade -- i.e., the exogenously given relative price of the exportable in terms of the importable.

The economy's salient feature is an investment technology with two basic characteristics: first, investment goods are (costlessly) produced by combining domestic goods and imports according to a constant-returns-to-scale specification:⁴

³ The model in this section is a somewhat simplified version of that in Serven (1994).

⁴ This specification of investment is similar to that used by Gavin (1992b) and Serven (1992, 1994).

$$J = J(J_N, J_F) \quad (1)$$

where J_N and J_F respectively denote domestic and foreign goods used as inputs to the investment process, and the function $J(\cdot)$ is homogeneous of degree one. Second, the installation of new investment goods involves convex costs, assumed quadratic for simplicity. Thus, total investment J differs from effectively installed new capital I :

$$J = I + \frac{\phi}{2} \frac{I^2}{K} \quad (2)$$

where the positive parameter ϕ measures the slope of marginal installation costs. For simplicity, we abstract from depreciation, so that net capital accumulation equals the installation of new capital.

The homogeneity of $J(\cdot)$ allows a two-stage investment decision: at the first stage, total investment is determined; its cost-minimizing allocation between domestic goods and imports can be decided at the second stage. Specifically, the investment technology (1) implies the existence of an exact investment price index $p_K = p_K(\pi)$, with $p_K' > 0$ and $p_K'' < 0$, that measures the (minimized) cost in terms of imports of one unit of real investment⁵.

The economy is populated by a representative, infinitely-lived agent who can borrow and lend at the given world interest rate r^* in terms of imports.⁶ Work entails no disutility, and hence the agent supplies inelastically her entire labor endowment, which for notational simplicity will be ignored. Thus, the production technology can just be expressed as $Y = Y(K)$, where Y denotes real output of the domestic good, with $Y' > 0$, $Y'' < 0$. The agent's objective is to maximize the utility functional

$$\int_0^{\infty} \exp(-\beta t) \frac{[C(C_N, C_F)]^{1-\theta}}{1-\theta} dt$$

⁵ Actually, homotheticity of $J(\cdot)$ would be sufficient to permit two-stage investment budgeting, although the price index in the text would then depend on both π and J . See also Hayashi and Inoue (1991) for a similar two-step specification of investment decisions.

⁶ Alternatively, r^* could be given in terms of exports. The assumption in the text is probably more realistic for the case of a small, price-taking economy.

where β is the discount rate, $1/\theta$ is the elasticity of intertemporal substitution in consumption, C_N and C_F respectively denote the instantaneous consumption of domestic and imported goods, and again for analytical convenience the function $C(\cdot)$ will be assumed homogenous of degree one. Thus, just like in the case of investment, consumption decisions can be characterized as the result of a two-stage budgeting process. C can be interpreted as the real consumption index, and the expenditure function associated with it can be expressed $p_c(\pi)C$, where the exact consumption price index p_c (with $p_c' > 0$ and $p_c'' < 0$) represents the (minimized) cost in terms of the importable of one unit of real consumption.

Putting all these pieces together, the representative agent's problem can be written

$$\text{Maximize} \quad \int_0^{\infty} \exp(-\beta t) \frac{C(t)^{1-\theta}}{1-\theta} dt \quad (3a)$$

$$\text{subject to} \quad \dot{K} = I \quad (3b)$$

$$\dot{A} = \left[\pi Y(K) - p_c(\pi)C - p_k(\pi) \left[I + \frac{\phi}{2} \frac{I^2}{K} \right] \right] + r^* A \quad (3c)$$

$$\lim_{t \rightarrow \infty} \exp(-r^* t) A = 0 \quad (3d)$$

K_0, A_0 given.

The right-hand side of (3c) is just the agent's current account surplus, with A denoting her net foreign assets; in turn, (3d) rules out the trivial solution of unbounded external borrowing. The current-value Hamiltonian for this problem is

$$H = \frac{C^{1-\theta}}{1-\theta} + \lambda \left[\pi Y(K) - p_c(\pi)C - p_k(\pi) \left[I + \frac{\phi}{2} \frac{I^2}{K} \right] + r^* A \right] + QI \quad (4)$$

where λ and Q are the shadow values of the stocks of foreign assets and capital, respectively. It will be useful to define $q \equiv Q/\lambda$ as the shadow value of capital *in terms of foreign assets*; then the first-order conditions for this problem include, in addition to (3b)-(3d), the following:

$$C = \left[\frac{1}{\lambda p_c(\pi)} \right]^{\frac{1}{\gamma}} \quad (5a)$$

$$I = \dot{K} = \frac{K}{\phi} \left[\frac{q}{p_K(\pi)} - 1 \right] \quad (5b)$$

$$\dot{\lambda} = (\beta - r^*) \lambda \quad (5c)$$

$$\dot{q} = \beta q - \left[\pi Y'(K) + p_K(\pi) \frac{\phi}{2} \left(\frac{\dot{K}}{K} \right)^2 \right] \quad (5d)$$

Equation (5a) is just the standard characterization of the optimal consumption path. In turn, (5b) is Tobin's investment rule, linking capital accumulation to the shadow value of capital relative to its replacement cost, with both measured in terms of foreign assets. As (5c) makes clear, a stationary solution for the model cannot exist unless the rate of time preference equals the world interest rate, as will be assumed henceforth⁷; in such case, the shadow value of foreign assets λ must remain *constant* along the adjustment path. Finally, (5d) is the arbitrage condition describing the trajectory of q .

Combining (5a) with the budget constraint (3c-d), it is straightforward to solve for the equilibrium value of λ :

$$\lambda = \left[\frac{A(t) + W(t)}{\int_t^{\infty} e^{-r^*(u-t)} [p_c(\pi(s))]^{1-\frac{1}{\gamma}} ds} \right]^{-\gamma} = \left[\frac{A_0 + W_0}{\int_0^{\infty} e^{-r^*s} [p_c(\pi(s))]^{1-\frac{1}{\gamma}} ds} \right]^{-\gamma} \quad (6)$$

where the second equality follows from the constancy of λ over time, and W denotes non-financial wealth, defined as

$$W(t) = \int_t^{\infty} e^{-r^*(u-t)} \left[\pi(s) Y(K(s)) - p_K(\pi(s)) \left(\dot{K}(s) + \frac{\phi}{2} \frac{(\dot{K}(s))^2}{K(s)} \right) \right] ds \quad (6')$$

⁷ See Cha (1993) for an analysis of permanent terms-of-trade shocks in an intertemporally-optimizing framework which allows the rate of time preference to differ from the world interest rate. Unlike this paper, however, Cha assumes that investment goods are produced domestically, and therefore output and the capital stock are wholly unaffected by terms of trade changes.

Thus, W is the present discounted value of the entire future stream of output *net* of investment expenses; $A + W$ therefore represents total wealth (financial plus non-financial) in terms of foreign goods.⁸ Replacing (6) into (5a) above, optimal consumption can be expressed:

$$C(t) = [A(t) + W(t)] \left[\frac{[p_c(\pi(t))]^{-\frac{1}{\theta}}}{\int_0^{\infty} e^{-r \cdot (t-s)} [p_c(\pi(s))]^{1-\frac{1}{\theta}} ds} \right] \quad (7)$$

Consumption behavior depends on two factors: first, total wealth; and second, intertemporal price speculation (to use Obstfeld's (1983) terminology), captured by the term in large square brackets in the above expression, that reflects the sensitivity of consumption to the present and future anticipated path of consumption prices. This will be an important issue in what follows, and can be highlighted by time-differentiation of (5a) above, which yields:

$$\frac{\dot{C}}{C} = \frac{1}{\theta} \left[r - \frac{p_c(\pi)}{p_c(\pi)} - \beta \right] = - \frac{1}{\theta} s_c(\pi) \frac{\dot{\pi}}{\pi} \quad (8)$$

where $s_c(\pi) \equiv \pi p_c'(\pi)/p_c(\pi)$ is the share of domestic goods in consumption expenditure. This is just a restatement of Dornbusch's (1983) well-known characterization of the optimal consumption path: as long as consumption has some domestic content (i.e., $p_c \neq 1$), it must follow a rising (declining) path if the terms of trade are worsening (improving). The reason is that anticipated terms of trade deterioration raises the real interest rate *in terms of consumption* above the rate of time preference, encouraging substitution towards the future; anticipated terms-of-trade improvement has the opposite effect. The slope of the consumption path is determined by the elasticity of intertemporal substitution $1/\theta$ and the share of domestic goods in consumption expenditure; the larger they are, the higher the

⁸ It is important to note that λ behaves like an asset price, and in the absence of any unanticipated shocks must remain constant at the value given in the text; in a closely related framework, this is underscored by Obstfeld (1983), who also derives an expression analogous to (6).

sensitivity of consumption growth to anticipated terms-of-trade changes.⁹

To explore the effect of changing terms of trade on the trajectory of investment, use (5d) to write:

$$\frac{d}{dt}\left(\frac{q}{p_K(\pi)}\right) = \left[r^* - s_K(\pi)\frac{\dot{\pi}}{\pi}\right] \frac{q}{p_K(\pi)} - \left[\frac{\pi}{p_K(\pi)}Y'(K) + \frac{\phi}{2}\left(\frac{K}{K}\right)^2\right] \quad (5d')$$

where, like with consumption, $s_K(\pi) = \pi p_K'(\pi)/p_K(\pi)$ is the share of domestic goods in investment expenditure. Thus, terms of trade changes impact on the time path of q/p_K -- and thereby of investment -- through two channels. First, as long as capital has some import content, terms of trade changes affect the value of the marginal product of capital relative to its price, $\pi Y'/p_K(\pi)$. Second, analogously with consumption, to the extent that investment has some domestic content anticipated terms of trade changes are also reflected in the real interest rate *in terms of capital goods* (the first term in brackets in the right-hand side): pending an expected terms of trade rise (fall), the real interest rate in terms of capital is below (above) r^* ; ceteris paribus, this reduces (raises) the user cost of capital and provides an incentive for the intertemporal reallocation of investment towards (against) the present.¹⁰ The extent to which these two forces impact on the time path of capital accumulation depends on $1/\phi$, which in this sense provides a measure of intertemporal substitutability analogous to that given by $1/\theta$ in the case of consumption.

The discussion has been limited so far to the *intertemporal* allocation of *aggregate* consumption and investment. However, their cost-minimizing *intra-temporal* allocation between domestic goods and imports follows immediately from Shephard's lemma:

$$C_N = p_C'(\pi) \cdot C \quad (9a)$$

$$C_F = [p_C(\pi) - \pi p_C'(\pi)] \cdot C \quad (9b)$$

⁹ In turn, whether consumption *expenditure* $p_C C$ moves over time in the same or in opposite direction to the terms of trade depends on whether θ is larger or smaller than unity, respectively.

¹⁰ This issue is explored at length in Serven (1992).

$$J_N = p'_K(\pi) \cdot \left(1 + \frac{\phi}{2} \frac{r}{K}\right) \quad (9c)$$

$$J_F = [p_K(\pi) - \pi p'_K(\pi)] \cdot \left(1 + \frac{\phi}{2} \frac{r}{K}\right) \quad (9d)$$

This completes the description of the model.¹¹ Its dynamics are discussed next.

3. Equilibrium dynamics

The model's dynamics can be summarized in the time paths of the shadow price of capital q , the stock of capital, and foreign assets. In fact, the dynamics are recursive, with the time paths of q and K determined by (5b) and (5d), independently of the foreign asset stock. Further, while the capital stock is a predetermined variable, its shadow value q is free to jump at any point in time in response to unanticipated shocks or to the arrival of new information about the future paths of the exogenous variables.

For given terms of trade π , the top panel of Figure 1 depicts the dynamics of the capital stock and its shadow value near the long-run equilibrium. Along the horizontal KK line, $q = p_K(\pi)$ or, in words, the shadow value of capital equals its replacement cost; therefore, investment is zero and the capital stock is constant. In turn, along the downward-sloping QQ line, $q = \pi Y'(K)/r^*$, and hence q is constant (from (5d)). The long-run equilibrium is at E where the KK and QQ lines intersect; at such point,

$$\bar{\pi} Y'(\bar{K}) = r^* p_K(\bar{\pi}) \quad (11)$$

where a bar over a variable denotes its steady-state level. In words, the value of the marginal product

¹¹ In fact, there is implicitly one more relation – namely, the clearing condition for the domestic goods market – which can be used to determine the economy's real exports. Using X to denote the latter, this would read:

$$Y = C_N + J_N + X$$

of capital equals its user cost, given by the real interest rate times the price of capital goods. The long-run equilibrium is a saddlepoint, and the negatively-sloped line SS depicts the unique convergent trajectory. Along the SS line, q and K move in opposite directions towards the long-run equilibrium: intuitively, as the capital stock rises (falls) towards its steady-state level, investment must simultaneously decline (rise) towards zero.

[Figure 1]

Consider now the trajectory of consumption and the current account. Under constant terms of trade, it follows from (5) and (6) that real consumption and total wealth $[A + W]$ must be constant as well. From (7), consumption equals $\bar{C} = r^*[A + W]/p_c(\bar{\pi})$, which is just *permanent income* – i.e., the annuity value of total wealth -- in terms of consumption goods. Therefore saving equals the difference between current income (inclusive of interest on net foreign assets) and permanent income:

$$S(t) = \bar{\pi}Y(K(t)) + r^*A(t) - r^*[A(t) + W(t)] = \bar{\pi}Y(K(t)) - r^*W(t)$$

and the current account balance is

$$\dot{A}(t) = S(t) - p_K(\bar{\pi})J(t) = \bar{\pi}Y(K(t)) - r^*W(t) - p_K(\bar{\pi}) \left[\dot{K}(t) + \frac{\phi}{2} \frac{(\dot{K}(t))^2}{K(t)} \right] = -W(t) \quad (12)$$

where the last equality follows from (6'); thus, the current account deficit equals the rate of change of non-financial wealth¹².

However, it is important to note that near the steady-state equilibrium the current account balance is determined by the trajectory of investment alone, because along the adjustment path any deviation of

¹² This can be seen to follow directly from the constancy of total wealth $A + W$ under constant terms of trade; see (6) in the text.

saving from its long-run level (equal to zero¹³) is just of second-order magnitude. This can be seen by recalling that, from the above expressions, saving equals the difference between current output (in terms of imports) and the annuity value of non-financial wealth r^*W . But near the steady state non-financial wealth can be approximated as¹⁴:

$$W(t) = \frac{\bar{\pi} Y(K(t))}{r^*} + \frac{1}{r^*} \left[\bar{\pi} Y'(\bar{K}) - r^* p_K(\bar{\pi}) \right] \int_t^{\infty} e^{-r^*(t-s)} \dot{K}(s) ds \quad (13)$$

From (11) above, the term in square brackets is zero, and therefore non-financial wealth just equals the capitalized value of *current* output $\bar{\pi} Y(K(t))/r^*$. The intuitive reason is that, near the long-run equilibrium, ongoing net investment and the ensuing change in output over time have no first-order impact on non-financial wealth, because each additional unit of capital earns a marginal return equal to its user cost -- a simple consequence of the envelope theorem.

Thus, under constant terms of trade, saving equals zero near the steady state. Equivalently, current and permanent income are equal up to a first-order approximation and, from (7) above, consumption equals current income:

$$C(t) = \left[\frac{r^* A(t) + \bar{\pi} Y(K(t))}{p_C(\bar{\pi})} \right] \quad (7')$$

¹³ Long-run saving must equal zero as a consequence of the assumption of no capital depreciation. With nonzero depreciation, long-run saving would be positive instead; nevertheless, with constant terms of trade, near the steady state saving would remain constant at its long-run level along the adjustment trajectory, up to a first-order approximation.

¹⁴ Here we use the fact that near the long-run equilibrium the quadratic adjustment-cost component of investment is only of second-order magnitude and can be ignored; however, see Gavin (1992a) for a discussion of the practical relevance of such second-order effects. In the text we employ the first-order approximation

$$Y(K(s)) = Y(K(t)) + \int_t^s \left[\frac{d}{ds} Y(K(s)) \right] ds = Y(K(t)) + \int_t^s Y'(\bar{K}) \dot{K}(s) ds$$

This in turn implies that the current account deficit is equal to investment expenditure. Hence, under constant terms of trade the accumulation of capital and foreign assets near the steady state must proceed in *opposite* directions: capital accumulation (decumulation) must be matched by a current account deficit (surplus).¹⁵ This inverse relationship between the stocks of capital and foreign assets along the adjustment path is captured by the downward-sloping AA line in the bottom panel of Figure 1.

4. Terms-of-trade shocks

A permanent terms-of-trade improvement

The consequences of a permanent terms-of-trade shock in this model can be easily illustrated. Assume that the economy is at the long-run equilibrium E_0 in Figure 2, with a capital stock K_0 and foreign assets A_0 , when the terms of trade rise unexpectedly and permanently from π_0 to π_1 ; since the terms of trade remain flat after the initial rise, the consumption- and investment-based real interest rates remain unchanged at r^* .

Consider first the impact on the capital stock and its shadow value, already analyzed by Gavin (1992b) and Serven (1992) in closely related (but simpler) models. In Figure 2, the permanent increase in the terms of trade shifts both the QQ and KK schedules upward, to $Q'Q'$ and $K'K'$, respectively. The QQ schedule shifts vertically by the full amount of the terms of trade change; in turn, the precise extent of the shift of KK depends on the domestic content of investment goods. If capital goods are fully domestic, as conventionally assumed, then $p_K(\pi) = \pi$, and the KK schedule would also shift by the full amount of the terms of trade improvement. In such case, the new long-run equilibrium would be at \tilde{E} , with an unchanged capital stock (and real output); likewise, the current account and the foreign asset stock would remain wholly unaffected.

¹⁵ The same result is obtained by Sen and Turnovsky (1989) and Murphy (1992).

[Figure 2]

If capital goods have an import content, however, the KK schedule shifts by less than the QQ line, and therefore the new long-run equilibrium at E_1 in Figure 2 is to the right of the initial one, and involves a higher capital stock. The reason is that the terms of trade improvement raises the marginal product of capital in terms of foreign goods above its real user cost (see (11) above), and more so the higher the import content of investment goods¹⁶; thus the optimal capital stock rises to K_1 . In the short run, the shadow value of capital jumps to q' on the new convergent path $S'S'$ and investment rises; thereafter, the adjustment involves a rising capital stock and falling q , with investment gradually declining towards zero.

What about consumption and saving? From (7'), real consumption jumps on impact to the new constant level

$$C_1 = \frac{[r^* A_0 + \pi_1 Y(K_0)]}{p_c(\pi_1)}$$

Differentiating this expression with respect to π_1 , and evaluating the result at $\pi_1 = \pi_0$, the change in consumption can be expressed

$$\frac{dC_1}{d\pi} \Big|_{\pi_1 = \pi_0} = \frac{1}{p_c(\pi_0)} \left[Y(K_0) - s_c(\pi_0) \left[r^* \frac{A_0}{\pi_0} + Y(K_0) \right] \right] = \frac{1}{p_c(\pi_0)} [C_{F0} - r^* A_0]$$

where C_{F0} denotes consumption imports at the initial equilibrium. Since at the initial equilibrium the current account was balanced at zero investment, $C_{F0} - r^* A_0 = \pi_0 [Y(K_0) - C_{N0}]$, which in turn equals the value of exports in terms of foreign goods at the initial steady state; thus, the new consumption level must

¹⁶ Clearly, this effect is maximum in the extreme case of zero domestic content of investment ($p_K = 1$), in which the user cost of capital remains unchanged and therefore the KK schedule does not shift at all.

be higher -- as long as the original equilibrium involves positive exports of the domestic good.¹⁷

After the initial change the terms of trade remain at π_1 , and therefore the adjustment proceeds along the lines discussed in the previous section: saving remains unchanged at zero¹⁸ and, since investment has risen, the current account must be in *deficit* throughout the adjustment to the new long-run equilibrium -- exactly the reverse of the Laursen-Metzler effect.¹⁹ Thus, as capital is accumulated the foreign asset stock declines from A_0 to A_1 along the AA line in the bottom panel of Figure 2.

A transitory terms of trade improvement

Consider now the case of a purely temporary terms of trade windfall, which from the practical viewpoint is probably a more interesting scenario.²⁰ Assume that at time 0 the terms of trade rise unexpectedly from π_0 to π_1 , and it is immediately recognized that at time T they will decline back to π_0 permanently.

What are now the consequences for consumption, investment and the current account ? The answer is a bit more complex than in the previous experiment because, as discussed earlier, with time-varying terms of trade the equilibrium paths of both consumption and investment reflect in part the effects of changing real interest rates in terms of consumption and investment goods, respectively.

¹⁷ Otherwise, as noted by Obstfeld (1983), the domestic good would be imported rather than exported, and the rise in the terms of trade would really amount to a loss rather than a windfall.

¹⁸ More precisely, the change in saving is only of second-order magnitude, as described earlier. The fact that with homothetic preferences saving is wholly unaffected by unanticipated permanent terms-of-trade changes was rigorously shown by Svensson and Razin (1983) and Svensson (1984). However, this ceases to be true if non-traded goods are introduced in the analytical framework; see Gavin (1990).

¹⁹ Sen and Turnovsky (1989), using a model broadly similar to the present one -- but assuming that capital goods have no import content and highlighting the labor/leisure decision -- likewise find that a permanent terms-of-trade improvement may cause a current account deterioration, through an investment boom triggered off by substitution between consumption and leisure. More generally, in a two-sector framework with both traded and non-traded goods, a permanent terms-of-trade improvement unambiguously causes an investment boom if nontraded goods are capital-intensive. If non-traded goods are instead labor-intensive, an investment boom can still result if the import content of capital used in the export sector is high enough.

²⁰ See Cuddington and Urzua (1989) and Mendoza (1992) for evidence that the majority of observed terms-of-trade fluctuations are purely transitory.

Consider first the response of investment. In the long run, with the terms of trade unchanged at π_0 , the capital stock must remain at its original level K_0 . Pending the anticipated terms of trade decline, however, investment is subject to the influence of two factors. On the one hand, the price of new capital is transitorily high and expected to fall back to $p_K(\pi_0)$; as discussed earlier, this raises the real interest rate in terms of capital goods and, *ceteris paribus*, discourages investment prior to T – more so the larger the domestic content of investment goods. On the other hand, the transitory terms of trade gain also raises the profitability of capital, boosting the value of its marginal product above its user cost (i.e., $\pi_1 Y'(K_0) > r^* p_K(\pi_1)$); this amounts to a transitory investment incentive, which is larger the higher the import content of capital.

Two extreme scenarios deserve mention. If capital has no domestic content ($p_K = 1$), its relative price is unaffected by the terms of trade improvement, the real interest rate in terms of capital is constant at r^* , and the first of the two effects above is nil; therefore investment must rise in the short run. Conversely, if capital is fully domestic (i.e., $p_K(\pi) = \pi$, as conventionally assumed), then the profitability effect disappears, and investment must fall in the short run.

In the general case, however, the short-run response of investment reflects the two opposing forces above, and is therefore ambiguous.²¹ Its sign depends on three key factors: (i) the import content of capital: the higher it is, the larger the transitory incentive and the smaller the disincentive just described. (ii) The persistence of the terms of trade gain, as measured by T : the larger T , the longer-lasting the profitability increase and the more distant in the future the rise in the real interest rate in terms of capital, thus making it more attractive to install extra capital in the short run. (iii) Marginal installation costs (as measured by ϕ): the costlier it is to install capital, the lesser the net payoff from adding capital now and removing it later in response to a purely transitory profitability rise.

Figure 3 depicts two possible scenarios. In both cases the economy starts from the initial

²¹ The intuitive argument that follows is formalized in the appendix.

equilibrium at E_0 , with S_0S_0 representing the convergent path. If the terms of trade rise were permanent rather than transitory, the new long-run equilibrium would be at E_1 , with the convergent path $S'S'$, as discussed earlier. Figure 3 (a) corresponds to the case in which the transitory profitability incentive is large -- either because the import content of capital is high, or the terms-of-trade improvement is long-lasting -- relative to marginal installation costs. Thus, on impact q jumps to a point such as q' above $p_K(\pi_1)$, so that q/p_K rises and net investment turns positive. During the period of high terms of trade, the system displays a clockwise motion: q falls monotonically, and capital accumulation eventually must give way to decumulation as the anticipated terms of trade fall draws near. At time T , when the terms of trade return to their initial level π_0 , the system must be at a point such as F_T on the original convergent path S_0S_0 . The price of capital goods declines back to $p_K(\pi_0)$, q/p_K rises, and investment jumps upward²²; the adjustment then involves continued capital decumulation (albeit at a reduced rate) and rising q .

Figure 3(b) portrays an alternative scenario of low import content of capital, short-lived terms of trade improvement, and/or high marginal installation costs. In such case, the terms of trade windfall causes q to rise initially by less than p_K , and therefore net investment turns negative. Over time, both q and K keep falling; at instant T , when the terms of trade deteriorate back to π_0 , the system must be at a point like F_T on S_0S_0 . The fall in p_K then causes investment to rise, and the system travels along the S_0S_0 locus towards the initial steady state.

[Figure 3]

²² Since the terms of trade deterioration at time T is perfectly anticipated, q cannot jump at that instant; hence $q/p_K(\tau)$ must rise abruptly, and so must investment. Notice also that at time T the capital stock may be above or below K_0 . In the latter case, net investment turns from negative to positive; in the former (depicted in Figure 3a), it remains negative, but decelerates toward zero.

Let us now turn to the consumption response to the temporary terms-of-trade windfall; in a context of fixed output and no investment, this has been studied by Obstfeld (1983). The transitory windfall must raise welfare, and therefore real consumption must rise above its initial level C_0 at least at *some* point in the adjustment path. However, the new consumption trajectory need not be *uniformly* above C_0 . The reason is that the path of consumption reflects two forces: on the one hand, real wealth rises with the temporary terms of trade windfall; on the other hand, as long as consumption has some domestic content, the anticipation that the terms of trade will deteriorate at time T raises the consumption-based real interest rate prior to that date, encouraging intertemporal substitution towards the future. Thus, at instant T , when the terms of trade return to their initial level, the consumption-based real interest rate falls back to r^* and real consumption must show an upward jump, rising above C_0 ; thereafter, with no further changes in the terms of trade, consumption remains flat. Prior to T , however, consumption may be above or below C_0 depending on the strength of the intertemporal substitution effect.

Analytically, letting C_1 denote the consumption level prevailing during the period of high terms of trade, the appendix shows that it can be approximated as

$$C_1 = \left[\frac{r^* A_0 + \pi_1 Y(K_0) - e^{r^* T} (\pi_1 - \pi_0) Y(K(T))}{p_c(\pi_1)(1 - e^{-r^* T}) + e^{-r^* T} \left[p_c(\pi_0)^{1-\frac{1}{\theta}} p_c(\pi_1)^{-\frac{1}{\theta}} \right]} \right]$$

and therefore, for small terms of trade changes,

$$\left. \frac{dC_1}{d\pi_1} \right|_{\pi_1=\pi_0} = \left[\frac{[Y(K_0) - C_{N0}](1 - e^{-r^* T}) - e^{-r^* T} \frac{1}{\theta} C_{N0}}{p_c(\pi_0)} \right] \quad (14)$$

Thus, whether consumption rises or falls in the short run depends on three factors. First, the domestic content of consumption, captured by the initial consumption of the exportable C_{N0} : the larger it is, the bigger the incentive to postpone consumption and the more likely an initial consumption fall. Second, the anticipated persistence of the terms of trade windfall, as captured by T : the larger T , the more distant

in the future the anticipated decline in the price of consumption, and the lesser the incentive to postpone consumption. Third, the elasticity of intertemporal substitution $1/\theta$: the lower substitutability, the weaker the intertemporal substitution towards the future in response to the transitory incentive, and the less likely an initial consumption fall; in particular, $1/\theta \leq 1$ suffices to guarantee that consumption will increase in the short run.

After the initial impact, the consumption trajectory remains flat at C_1 until instant T ; at such date, it must rise discontinuously to its new long-run level. Using C' to denote the latter, (5a) implies that $C' = C_1[p_C(\pi_1)/p_C(\pi_0)]^{1/\theta}$. Using (14) above, we have

$$\left. \frac{dC'}{d\pi_1} \right|_{\pi_1=\pi_0} = \frac{(1 - e^{-r^*T})}{p_C(\pi_0)} \left[Y(K_0) - C_{N0} \left(1 - \frac{1}{\theta}\right) \right]$$

which is positive as long as the initial equilibrium involves positive exports of the domestic good; therefore, C' must be unambiguously above the initial consumption level C_0 .

Given this trajectory of consumption, what happens to saving? It is easy to see that, following the initial terms of trade improvement, saving *must* rise as a result of both intertemporal smoothing of the real income gain and intertemporal consumption substitution towards the future.²³ Pending the terms of trade deterioration, with consumption expenditure constant at $p_C(\pi_1)C_1$, saving will be rising further if the investment response is positive and real output is therefore growing; it will be declining in the opposite case. At time T , when the terms of trade return permanently to their initial level, saving returns to zero, as described in the previous section.

Finally, what happens with the current account? The above discussion clearly shows that, in contrast with the unambiguous current account deterioration resulting from a permanent terms of trade gain, the impact of a purely transitory windfall is much less clear-cut: while saving must rise

²³ However, if the world interest rate were fixed in terms of the exportable rather than the importable (as assumed), the consumption-based real interest rate would *fall* instead of rising, and the intertemporal substitution effect would run again the consumption smoothing effect; thus, the overall effect on saving would be ambiguous.

unambiguously in the short run, investment may rise as well in response to the temporarily higher profitability of imported capital. Thus, the sign of the change in the economy's saving-investment balance is in principle indeterminate. The only exception is the special case of zero import content of capital goods, in which investment is assured to fall; this reinforces the saving rise, and the current account must unambiguously improve.

Nevertheless, the earlier discussion has identified the three key factors that shape the current account response in the general case: (i) the import content of consumption and investment, (ii) the persistence of the terms of trade improvement, and (iii) the degree of intertemporal substitutability in consumption *and* investment.

Higher import contents moderate the transitory rise in consumption- and investment-based real interest rates, and therefore dampen the incentive to postpone expenditures; moreover, a larger import content of investment also leads to a more significant short-run improvement in the profitability of capital, thereby encouraging investment. Through both channels, higher import contents make a short-run current account deterioration more likely.

Likewise, the longer-lasting the improvement in the terms of trade, the more likely a short-run current account deficit: as the anticipated rise in consumption- and investment-based real interest rates becomes more distant in the future, the incentive to the intertemporal reallocation of expenditure against the present is reduced, while investment is additionally encouraged as the transitory profitability improvement becomes more persistent.²⁴

Finally, it is worth underscoring the mutually opposing influences on the current account of intertemporal substitutability in consumption and investment²⁵ -- with the latter measured by the inverse

²⁴ In the limit, as T approaches infinity, the current account would deteriorate like under the permanent shock: the incentive to postpone expenditures would vanish, the time path of consumption would be flat, and investment would necessarily rise in the face of a more and more persistent profitability improvement.

²⁵ A similar result is obtained in Servén (1994) in a related model concerning the current account response to permanent fiscal shocks.

of the installation cost parameter, $1/\phi$. With higher consumption substitutability, the short-run saving rise is larger and a current account improvement hence more likely. Conversely, higher investment substitutability (lower installation costs) favors a positive investment response to the transitory profitability improvement, which tends to result in current account deterioration.

Graphically, the bottom panels of Figure 3 (a) and (b) portray two possible scenarios of current account response. Scenario (a) assumes that the short-run investment rise (displayed in the top panel) outweighs the saving increase, and hence the current account initially turns into deficit. At first, the capital stock is rising and foreign assets are falling; however, as the anticipated terms of trade deterioration draws near, net investment decelerates and eventually turns negative, while the current account is improving and eventually turns into surplus. At instant T , when the terms of trade return to their original level, the figure assumes that the system is at $(K(T), A(T))$, with the capital stock above, and foreign assets below, the initial level.²⁶ The terms of trade deterioration then causes a rise in investment (which nevertheless remains negative) and a drop in saving, so that the current account deteriorates (but nevertheless remains in surplus). Thereafter, the adjustment involves an upward motion along the $A'A'$ line, parallel to AA through $(K(T), A(T))$, until the initial capital stock K_0 is restored, which involves a foreign asset stock equal to \bar{A} .

Scenario (b) in turn depicts the alternative case of an initial investment drop. The current account turns immediately into surplus, and the system displays a clockwise motion with falling capital and rising foreign assets; pending the terms of trade loss, the investment decline keeps accelerating and the current account improves further. At time T foreign assets must be above, and the capital stock below, their initial levels; investment rises abruptly and the current account turns into deficit. Thereafter, the system moves downward along the $A'A'$ line to reach the long-run equilibrium at the initial capital stock,

²⁶ As noted earlier, this need not be the case, and the opposite situation (capital stock undershooting and foreign asset overshooting) is also possible. In the latter case, the adjustment after time T would involve positive net investment and a current account deficit.

involving now an increased foreign asset stock.

5. Concluding Remarks

This paper has examined the impact of terms of trade shocks in an aggregate framework whose distinguishing characteristic is to allow for imports not only of consumption goods, but also of productive capital -- an essential feature of real-world economies that is nevertheless ignored in many open-economy aggregate models. The analysis has focused on the effects of unanticipated permanent and transitory terms-of-trade shocks on intertemporally-optimizing consumption and investment decisions.

The results can be summarized in three main points. First, as long as capital has an import content, permanent changes in the terms of trade alter the long-run capital stock and output in the same direction: an improvement in the terms of trade raises the profitability of capital and thereby increases the steady-state capital stock and output; a deterioration has the opposite effect. With capital accumulation subject to convex installation costs, the somewhat surprising consequence is that a permanent terms of trade gain must lead to an investment boom and a current account deficit, while a permanent loss must cause a surplus.

Second, the current account impact of a temporary terms of trade change is ambiguous. As the literature has amply documented, saving must rise transitorily with a temporary windfall and decline with a temporary loss. As this paper has shown, however, if capital goods have an import content investment may move in the same direction as saving, making the current account outcome indeterminate. The reason is that during a temporary windfall investment imports are transitorily cheap in terms of domestic output, and thus the profitability of capital is transitorily high; therefore, a short-term investment boom (followed later by a slump) may result. The opposite happens with a temporary terms of trade loss. The exception to this general ambiguity is the special case of zero import content of capital, in which investment is assured to fall with a transitory terms of trade gain and rise with a loss; under such extreme

scenario -- which is nevertheless the one assumed almost invariably in conventional aggregate models -- the Laursen-Metzler effect obtains: a temporary terms of trade deterioration causes a short-term current account deficit, and an improvement causes a surplus.

Third, the analysis has shown that in the general case the short-run current account response to a transitory shock depends on three key factors. One, the import contents of consumption and investment -- the higher they are, the lesser the saving response and the stronger the impact on the profitability of capital, making it more likely that a temporary windfall will lead to a short-run current account deficit (and a loss will lead to a surplus). Two, the persistence of the shock, which acts in the same direction -- the longer-lasting it is, the lesser the incentive to postpone (anticipate) consumption and raise (lower) saving in response to a temporary windfall (loss), and the stronger the incentive to raise (cut) investment in reaction to the short-term profitability rise (decline). Three, intertemporal substitutability in consumption and investment -- with the latter measured by (the inverse of) the slope of marginal installation costs --, which have mutually opposing influences on the saving-investment balance: higher consumption substitutability amplifies the saving response to temporary terms of trade shocks, making it more likely that a windfall will cause a short-term surplus and a gain will cause a deficit. Conversely, higher investment substitutability (i.e., lower installation costs) magnifies the investment response to temporary profitability changes, which tends to result in a short-term investment boom (and a likely current account deterioration) in response to a transitory windfall, and a slump (and current account surplus) in response to a temporary loss.

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where $\mathbf{A} = \mathbf{A}(\mathbf{z})$ is the matrix of the linearized system (1.1) at the point \mathbf{z} .

$$\mathbf{A} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \quad \text{for } \mathbf{z} = \begin{pmatrix} 0 \\ 0 \end{pmatrix},$$

$$\mathbf{A} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} + \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \quad \text{for } \mathbf{z} = \begin{pmatrix} 1 \\ 0 \end{pmatrix},$$

$$\mathbf{A} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} + \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \quad \text{for } \mathbf{z} = \begin{pmatrix} -1 \\ 0 \end{pmatrix}.$$

Therefore, we have

$$\mathbf{A} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}$$

and the corresponding fundamental matrix is $\mathbf{F}(\mathbf{z}, t) = \begin{pmatrix} \cos t & \sin t \\ -\sin t & \cos t \end{pmatrix}$.

By the Floquet theory, the monodromy matrix \mathbf{M} is the value of $\mathbf{F}(\mathbf{z}, t)$ at $t = 2\pi$.

Therefore, the monodromy matrix \mathbf{M} is the value of $\mathbf{F}(\mathbf{z}, t)$ at $t = 2\pi$. It is easy to see that the monodromy matrix is

$$\mathbf{M} = \begin{pmatrix} \cos 2\pi & \sin 2\pi \\ -\sin 2\pi & \cos 2\pi \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}.$$

$$\mathbf{M} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \quad \text{for } \mathbf{z} = \begin{pmatrix} 0 \\ 0 \end{pmatrix},$$

and the corresponding fundamental matrix is $\mathbf{F}(\mathbf{z}, t) = \begin{pmatrix} \cos t & \sin t \\ -\sin t & \cos t \end{pmatrix}$.

$$\mathbf{M} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \quad \text{for } \mathbf{z} = \begin{pmatrix} 1 \\ 0 \end{pmatrix},$$

The sign of this expression is given by the term in square brackets; the latter is clearly increasing in T – the duration of the shock – and in $(1-s_p)$ – the import content of investment. Note also that the larger the adjustment cost parameter Φ , the smaller μ and hence the more likely is the term in brackets to be negative, leading to a short-run decline in investment.

2. The response of consumption to a temporary shock

To find the trajectory of consumption, it is necessary first to compute non-financial wealth. From (13) in the text, $W(T) = \pi_0 Y(K(T))/r^*$; thus, from (6') we have:

$$W(t) = \int_0^T e^{-r^*(t-s)} [\pi_1 Y(K(s)) - p_K(\pi_1) J(s)] ds + e^{-r^*(t-T)} \frac{\pi_0 Y(K(T))}{r^*}$$

Integrating using the same approximation as in fn. 14 in the text, we find

$$W(t) = \frac{\pi_1 Y(K(t)) + e^{-r^*(t-T)} (\pi_2 - \pi_1) Y(K(T))}{r^*}$$

Replacing this expression into (7) and evaluating the result at $t=0$, we obtain the expression for C_1 given in the text.

Figure 1
Equilibrium dynamics

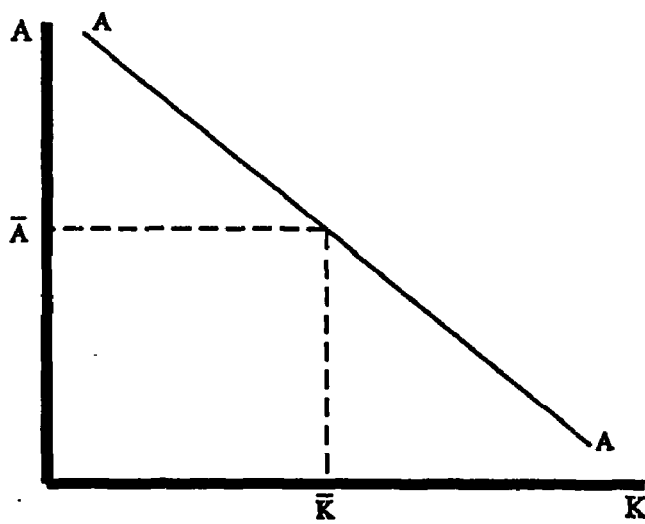
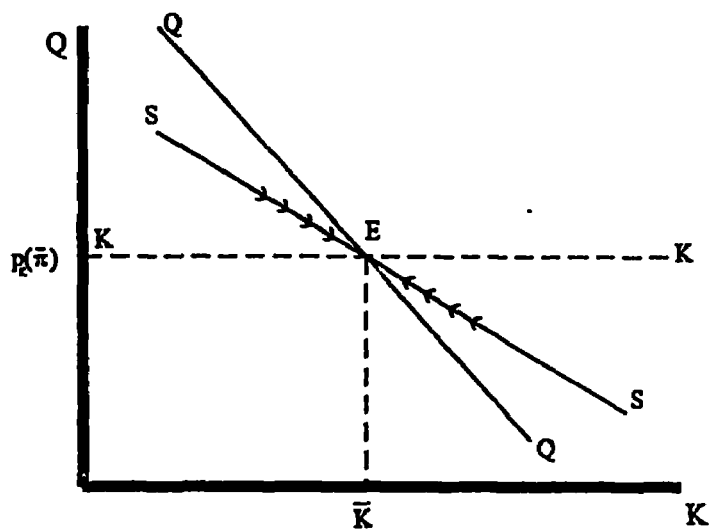


Figure 2

A permanent terms of trade improvement

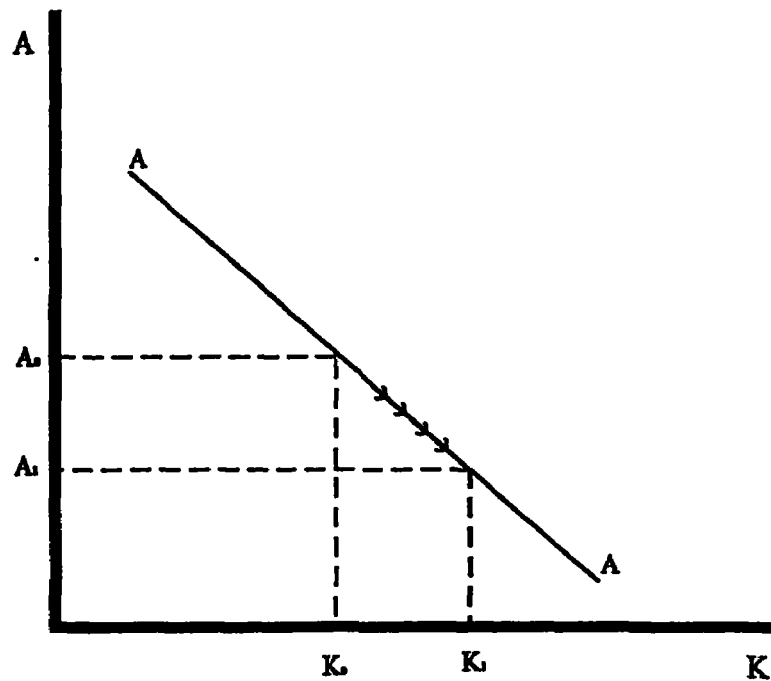
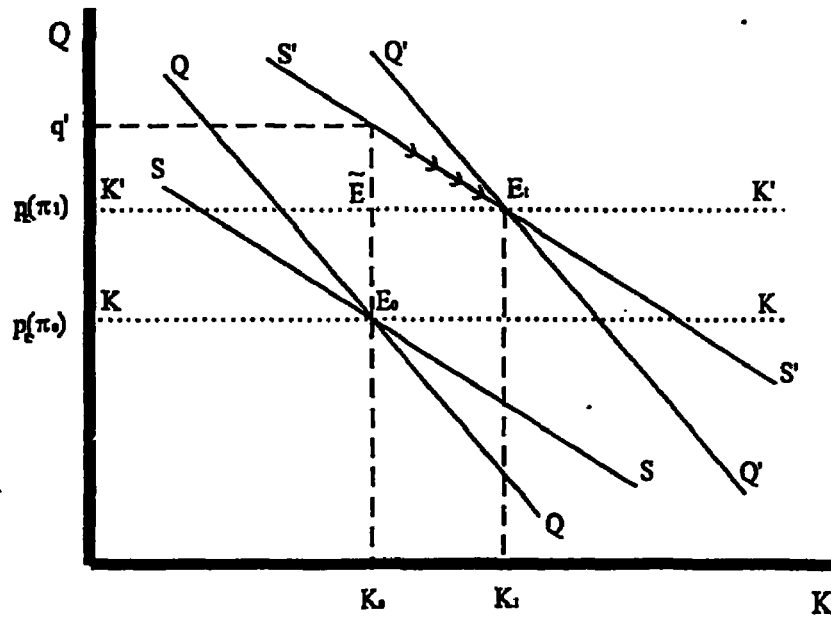
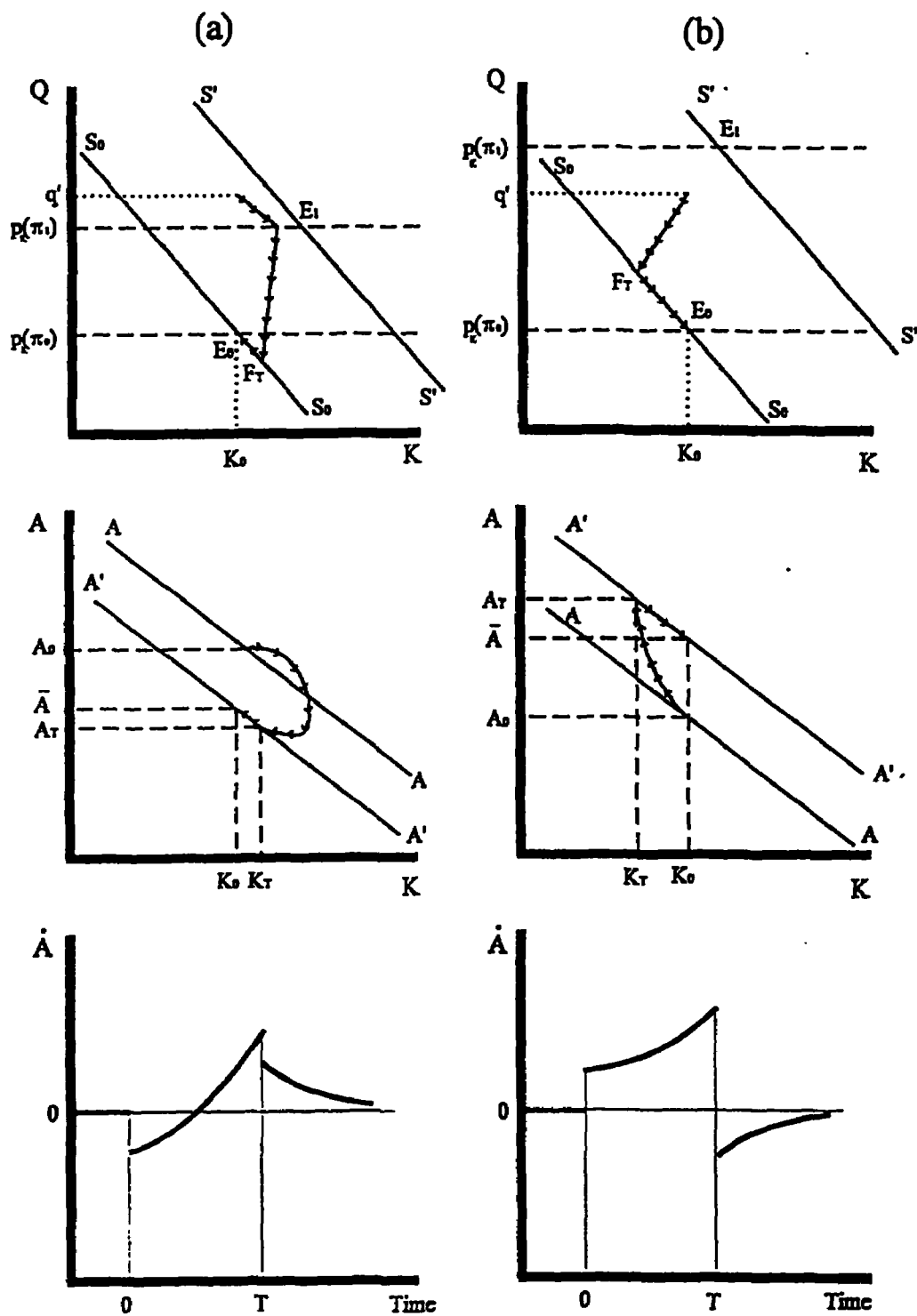


Figure 3
A transitory terms of trade improvement



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